Space Weather Technical Forecast

Issued on Monday, 04 December 2023 at 01:29 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: G1-G2 (Minor-Moderate geomagnetic storms) likely day 1 and 2 (04-05 Dec). Chance of isolated M-Class flares (R1-R2 Blackouts) days 1 and 2 (04-05 Dec).

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity is at Low levels with the largest flare of the past 24 hours a C4.0 flare at 03/0806 UTC from the southwest limb, with the likely source region ex-AR3494. There are nine sunspots on the disc. AR3500 (Dai/Beta-Gamma) in the southwest remains the largest and most significant region, though it continues to decay with reduced umbral and penumbral extent. Two new regions (AR3510 and AR3511) in the southeast, developed into small bipolar groups with fairly simple magnetic configurations. AR3507 developed into a simple, bipolar group with the emergence of minor spots of mixed polarity to the south of the moderately large H-spot. The remaining regions on the visible disc are mature and stable.

Despite a number of CME signatures evidenced in coronagraph imagery during the past 24 hours, none are considered Earth-directed. A filament that erupted from near AR3505 around 03/2200 UTC appears not to have lifted off energetically, however, further solar imagery is required to confirm that no significant CME has occurred.

Solar Wind / Geomagnetic Activity: Solar wind parameters have been indicative of a near background wind regime that has given way to the onset of the fast winds of a coronal hole high-speed stream, speculated to be the early arrival of CH76/-. Solar wind speeds, as observed by DSCOVR at L1 were background to slightly elevated for much of the period, varying between 390-450km/s. From 03/1600 UTC speeds have steadily risen to reach elevated levels, around 520km/s by the end of the UTC day. Density was between average and above average levels, with a peak of 31pppc at 03/1604 UTC. The Interplanetary Magnetic Field (IMF), Bt, was initially moderate, peaking at 9nT, before erratically falling to around 5nT by the end of the period. The north-south component of the IMF (Bz), was largely positive, fluctuating between +8/-6nT. Phi angle initially negative (towards the Sun), but became largely positive (away from the Sun) between 03/0200-0800 UTC, before turning mainly negative again from 03/0800 UTC. Resultant Geomagnetic activity was Quiet to Unsettled (Kp 1-3).

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux remained at Background levels. GOES16 high energy (greater than 2MeV) electron flux has been Background. The associated 24-hour fluence has remained below the Active threshold (1e8 integrated pfu) with a steady trend. The observation at 03/0000 UTC was 1.33e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Solar activity is expected to be Low with a chance for isolated M-flares (R1-R2 Blackouts) on days 1-2 (04-05 Dec), reducing to a slight chance on days 3-4 (06-07 Dec). The majority of the flare risk is attributed to AR3500 in the southwest.

Solar Wind / Geomagnetic Activity: A CME that left the sun late on 01 Dec has a chance to give a glancing impact at Earth late day 1 (04 Dec) or early day 2 (05 Dec), otherwise no Earth-

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directed CMEs feature in the forecast period. Solar winds have increased to Elevated levels, this is likely due to the early arrival of the fast wind from a large negative polarity coronal hole. Speeds should increase further on days 1 and 2 (04-05 Dec) to become Strong, probably peaking between 600-700km/s. Speeds should then slowly ease from day 3 (06 Dec) onwards, likely becoming Elevated by the end of day 4 (07 Dec).

Geomagnetic activity is expected to be Quiet to Unsettled early on day 1 (03 Dec), then forecast to increase to G1-G2/Minor-Moderate Storm (Kp5-6) levels late day 1 (04 Dec) and early day 2 (05 Dec). Following peak geomagnetic activity, indices should fall to Unsettled to Active by the end of day 2 (05 Dec), before becoming Quiet to Unsettled from day 3 (06 Dec) onwards.

Energetic Particles / Solar Radiation: GOES16 high energy proton flux is forecast to remain at background levels with no Solar Radiation Storms expected.

Electron flux is at background levels. Some recovery of flux to Moderate levels is possible on day 1 (04 Dec). Electron flux is then likely to decrease to background levels for a time given increased geomagnetic activity. An increase to High levels is likely by day 3 and 4 (06-07 Dec). The associated 24 hour electron fluence is expected to remain below the Active threshold, but with a chance of exceeding on day 4 (07 Dec).

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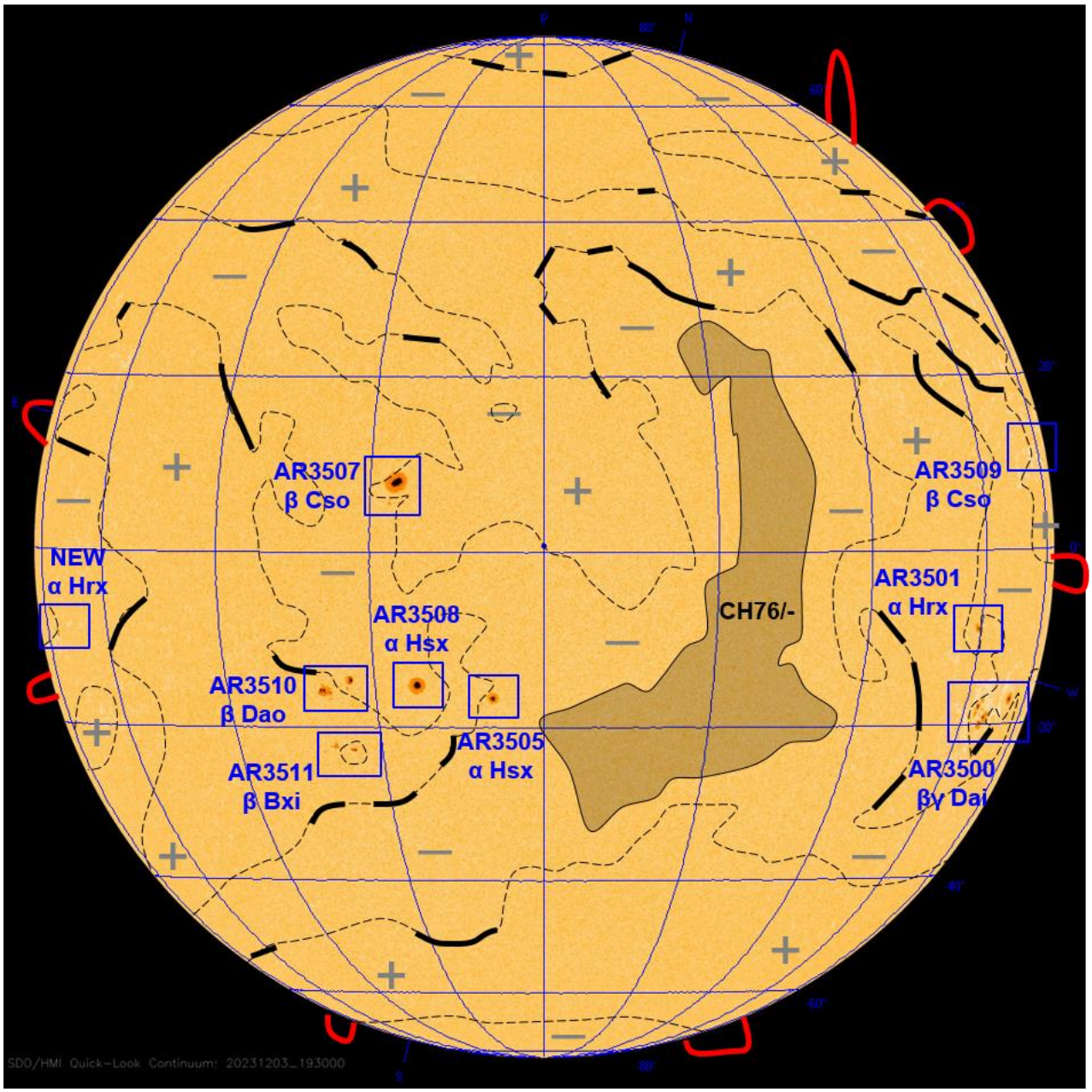
Figure 1. Solar Analysis Valid 03/1930 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

A CME that left the sun in association with the M1.1 flare from AR3500 at 01/2120 UTC has been analysed and modelled. Although the majority of the ejecta is forecast to pass ahead of and below Earth orbit, there is a chance of a glancing blow late day 1 (04 Dec) or early day 2 (05 Dec). A filament that erupted from near AR3505 around 03/2200 UTC appears not to have lifted off energetically, however, further solar imagery is required to confirm that no significant CME has occurred.

Solar winds have increased to Elevated levels. Solar wind parameters suggest this may be the early onset of the HSS from CH76/-. This coronal hole is a persistent feature and similar in size and position to the previous rotation. However during the previous solar rotation a CME arrival masked the initial influence of the coronal hole. Despite this, Strong winds of around 600-700km/s are expected at peak, though with slightly lower than average confidence in the highest speeds from this feature. This increase in speed from Elevated levels is forecast to take place during days 1 and 2 (04 and 05 Dec). Strong speeds should persist through to day 3 (06 Dec) before slowly easing to Elevated levels by the end of day 4 (07 Dec).

Geomagnetic activity is expected to be Quiet to Unsettled early on day 1 (03 Dec), then forecast to increase to G1-G2/Minor-Moderate Storm (Kp5-6) levels late day 1 (04 Dec) and early day 2 (05 Dec). Following peak geomagnetic activity, indices should fall to Unsettled to Active by the end of day 2 (05 Dec), before becoming Quiet to Unsettled from day 3 (06 Dec) onwards.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	70	50	5	1
Strong	G3	No	10	5	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
02/0440	Partial	M1.0 Flare AR3500	SW	585 km/s	04/1800 UTC	Chance of a glancing blow with limited shock

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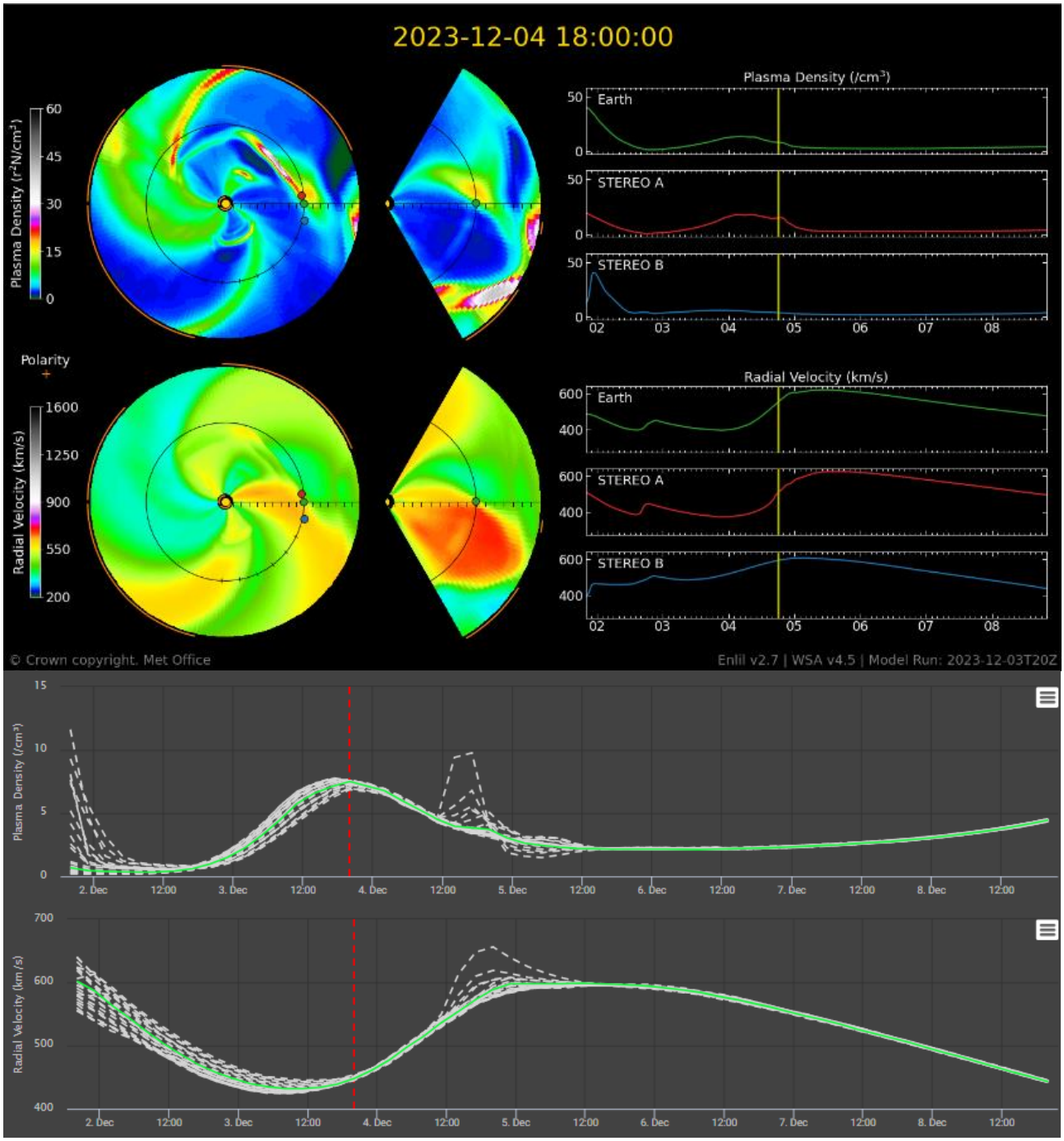
Figure 2: MOSWOC Enlil forecast with Ensemble set to 04/1800 UTC



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Radio Blackouts - X-Ray Flares:

The largest flare of the past 24 hours is a C4.0 flare at 03/0806 UTC from the southwest limb, with the likely source region ex-AR3494.

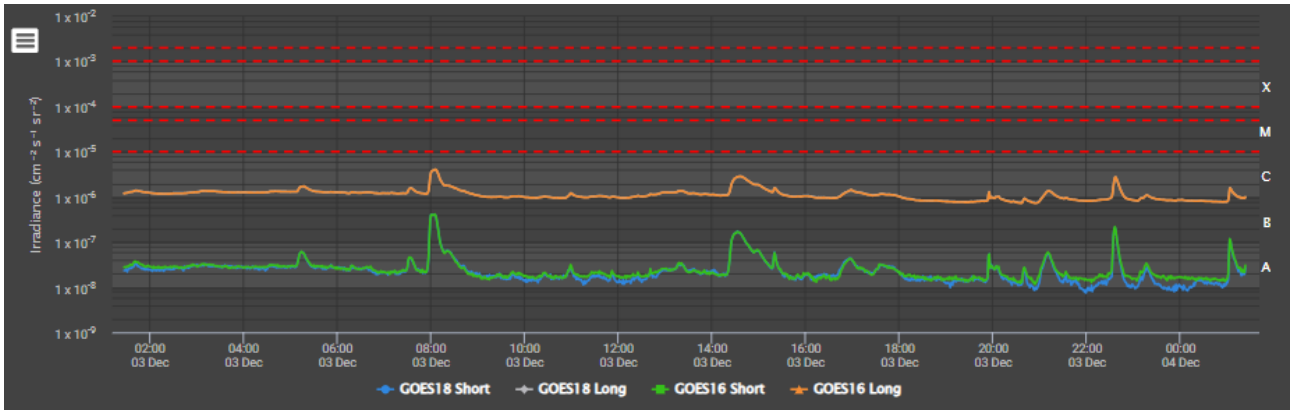
There are nine sunspot regions on the disc with the unnumbered region in the northwest now decayed. The largest spot on the disc is still AR3500 in the southwest, however it continues to slowly decay as the intermediate region reduces in size and separates. AR3507 in the northeast is now a simple, bipolar group with the emergence of minor spots of mixed polarity to the south of the moderately large H-spot. AR3510 and AR3511, both in the southeast have developed slightly. The remaining regions on the visible disc are mature and stable "H" spots.

A number of sunspots in the western hemisphere, including AR3500, are due to rotate over the western limb in the forecast period. No significant returning or new regions are expected to rotate over the eastern horizon in the coming days, so the likelihood of significant flares reduces overall in the absence of any notable developments on the visible disc.

Solar activity is expected to be Low with a chance for isolated M-flares (R1-R2 Blackouts) on days 1-2 (04-05 Dec), reducing to a slight chance on days 3-4 (06-07 Dec).

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	No	30	30	15	15
Very Active	R3 to R5 X Class	No	3	3	1	1

Figure 3: GOES 16/18 X-Ray flux



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Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES16 is currently at Background and expected to remain at this level. There is a very slight chance of S1/Minor Storm conditions being reached on days 1-2 (04-05 Dec) should any significant flares occur, mainly from AR3500 in the southwest, though the risk diminishes by day 3 as the region rotates off the visible disc.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	5	5	1	1
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

High Energy Electrons Event (≥ 2MeV):

Electron flux is at background levels with the Van Allen belts still suppressed following recent enhanced geomagnetic activity. Some recovery of flux to Moderate levels is possible on day 1 (04 Dec) before geomagnetic activity increases with the arrival of the HSS from CH76/- later in the day, continuing into early day 2 (05 Dec). An increase to High levels is likely by day 3 and 4 (06-07 Dec) as the electron belts relax back towards ambient positions.

The associated 24 hour electron fluence is expected to remain below the Active (1e8 integrated pfu) threshold. However, a rising trend is likely from day 2 (05 Dec) and more especially into days 3 and 4 (06-07 Dec) with a chance of exceeding the Active threshold on day 4. REFM is considered to be providing reasonable guidance, although the forecast increase in fluence is thought to be too quick to occur.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	1	5	40
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

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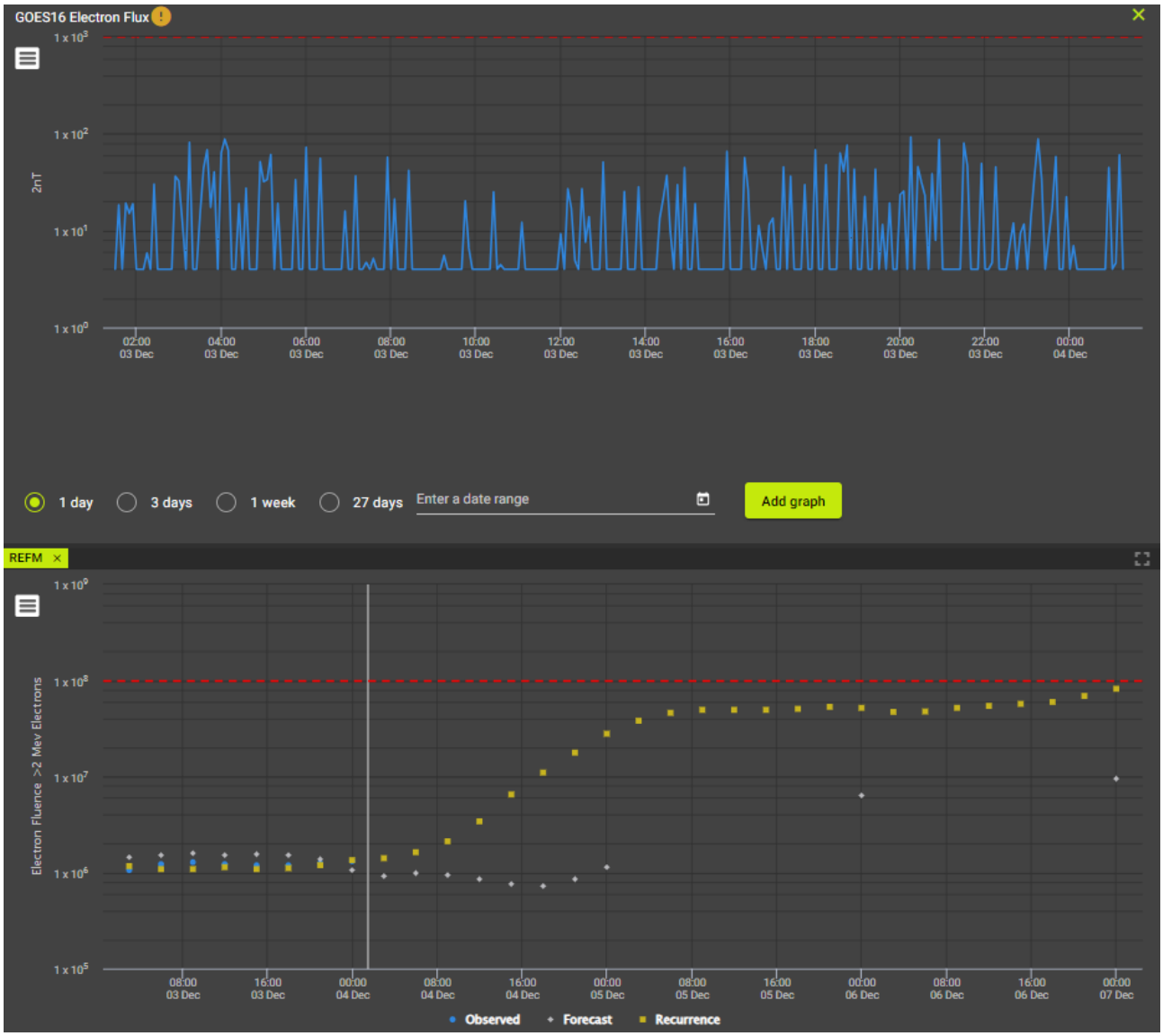
Figure 4: GOES16 >2MeV Electron flux (top) and MOSWOC Fluence forecast with recurrence (below)



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